ing the heat brought in and adding new quotas of ever colder and colder air to keep up the circulation.

14. Under certain conditions it may sometimes occur during the afternoon or early evening that the surface air high up on the hillside is warmer than the adjacent free air. These temperature relations will cause the warm surface air to convectively change places with the adjacent cool free air, and to this extent the rate of cooling of the surface air on the upper portion of such slopes will be increased for a time. Just as soon, however, as the temperature of this surface air has become the same as that of the adjacent free air at nearly the same level, the convective exchange, with a cooling effect, will cease, but a similar exchange will set up again in the reverse direction with a warming effect when the temperature of the surface layers has been reduced still lower as a result of radiation.

15. It therefore appears that during the nighttime the warm free air facing the slopes of a valley, acts as a great reservoir of heat which is drawn upon by the operation of the convective exchanges described in the foregoing to conserve the temperature of the adjacent hillsides and to prevent the fall of temperature that would otherwise result from the loss of heat by nocturnal radiation under clear skies—a fall that does occur at the bottom levels of the valley where convective exchanges are impossible or the quantity of free air is too small to afford material protection. The circulation described also forms, little by little during the nighttime, the stagnant river or lakelike mass of cold air that fills the lower levels of the valley to a greater and greater depth.

16. The surface of the river of cool air is defined by the simple condition that its temperature is greater than that of any adjacent air either above or below. This surface, moreover, is essentially horizontal except along the shore lines where the surface rises to meet the bank tangentially. In this region cooling is going on somewhat rapidly and the adjustment to equilibrium is not as yet complete. The shore lines of this river in the early morning hours locate the much desired thermal belt of the orchardist. How deep the river will be at dawn under average climatic conditions in a given valley, can best be established only by suitable observations and interpolations, although estimates thereof may probably be made from a careful study of the several physical elements of the problem.

17. The foregoing clearly indicates, it is believed, the essential characteristics and principles of air drainage as it actually occurs under hill and valley conditions, and the reasons thereof. Many minor details have necessarily been omitted, and the differences in results with essentially different conditions of topography, while affording interesting applications of the principles presented above, are not appropriate to the present discussion. The point of chief importance, perhaps, is the fact that the source of the heat that conserves the temperature of the slope surfaces is the great volume of warm *free* air facing the slope. The volume of this air near the bottom of the valley, as already stated, is too small to give material protection, such as is afforded at intermediate levels. While unlimited masses of free air may be available higher up, the temperature in these levels, even at midafternoon, may be lower than that of the adjacent surfaces. Consequently at first these are rapidly cooled by both radiation and the convective exchanges. Later on these exchanges have a warming effect and conserve the surface temperatures against radiation losses, but the actual temperature may be much below the requirements of agriculture.

VII.

PROTECTION AGAINST FROST IN GEORGIA.

By CHARLES F. VON HERRMANN, Section Director.

[Dated Weather Bureau, Atlanta, Ga., Nov. 27, 1914.]

The first shipment of peaches from Georgia by refrigerator cars on a commercial scale was made in 1884. The rapid increase of the industry is probably best indicated by the comparative number of trees of bearing age, since variations in the quantity of product is so largely dependent upon favorable or unfavorable climatic conditions. The number of peach and nectarine trees in Georgia in 1890 was 2,787,546, in 1900 it was 7,668,639, and in 1910, 10,609,119. The total value of orchard fruits produced annually now exceeds $3,000,000.

The principal peach-growing districts of Georgia lie northwest and south of Atlanta. According to the census of 1910 the number of peach trees in each county in the main sections were as follows:

Northwestern section.		*Fort Valley district.*	
County.	Number.	County.	Number.
Walker	283,000	Spalding	127,000
Chattooga	436,000	Upson	195,000
Whitfield	269,000	Monroe	145,000
Floyd	411,000	Meriwether	142,000
Gordon	322,000	Crawford	378,000
Bartow	586,000	Taylor	271,000
Pickens	187,000	Macon	576,000
Cherokee	163,000	Jones	432,000
Cobb	281,000	Houston	1,385,000

The development of methods of protection from frost has kept pace with the rapid growth of horticultural interests in Georgia. An impetus was given to the study of this question by the accidental production of a full crop of peaches in one orchard near Fort Valley in 1888, while the crop was a general failure throughout the State on account of late spring frosts. The woods west of this orchard (the Hiley orchard) were accidentally fired the night before the frost, and thick smoke settled over the orchard which helped to produce a full crop of peaches. A limb containing 35 peaches cut from an Elberta tree in the Hiley orchard was photographed and for many years figured in all the nursery catalogues.

Ten years later, in 1898, the use of smudge fires as the most efficient and practical means of protection from frost was quite general in Georgia, with varying degrees of success. The fuel most frequently used was coal tar with pine straw, and 20 to 25 fires to the acre were needed to produce a sufficiently dense smoke.

The severe freeze of February, 1899,[1] during which temperatures below zero, Fahrenheit, were experienced even to the southern limit of the State and which resulted in the death of many trees, marked decline in the shipment of peaches, and seems to have discouraged further efforts to protect the peach crop. Since 1899 the following years only have given full crops without the necessity for protection, viz: 1901, 1904, 1908, 1912, and 1914.

During the remaining 10 years the crop was generally a partial or complete failure on account of freezing weather in early spring or late frosts. The whole matter of protecting peaches in Georgia is now in a state of

[1] See MONTHLY WEATHER REVIEW, February, 1899, p. 69, and Chart XIII.

desuetude. Only here and there occasional efforts are made to protect peach orchards, generally by the older methods. There can be no doubt that by the application of the newer methods of protecting orchards most of the crop failures since 1890 could have been avoided, and it is unfortunate that peach growers have not kept abreast of the times in this respect.

The reasons for this notable lack of interest in the subject at present may be stated as follows:

1. A lack of knowledge of the newer and more efficient methods of orchard protection now successfully used in the West, which depend not so much on the protection afforded by smoke as on the actual warming up of the air in the orchard.
2. Lack of faith in the efficiency of the newer methods.
3. The expense involved, since it is known that devices for heating the air are expensive; their value depends upon a comparatively still air and numerous well-distributed fires. The cheapness of fuel and labor in Georgia, however, should not be forgotten.
4. It is though that peach trees can not bear full crops in successive years, therefore a full crop is not expected more than once in three years. The profits during the full years overbalance the losses during the lean years.
5. The lack of cooperation among neighboring orchardists.

In the early part of the year 1914 this matter was brought to the attention of about 60 of the largest peach growers in Georgia, by the official in charge of the local office of the Weather Bureau at Atlanta, and bulletins on the subject were widely distributed.

The use at present made of the frost warnings in Georgia, as far as known, is limited to efforts to protect small fruits, chiefly strawberries, of which 1,262,000 quarts were produced in 1909; also to protect truck crops and tobacco beds in the springtime by the usual methods of covering with straw, pine needles, cloth, or earth. In the aggregate the resulting saving must be considerable. The frost warnings when issued with the daily forecasts are available by free telephone distribution to over 75,000 people. The special frost warnings, however, are issued to only 23 addresses. In autumn the frost warnings are utilized not to protect, but to enable a farmer to gather as quickly as possible the crop threatened, as, for example, bell peppers and tomatoes, which are left on the plants as long as possible.

It is evident that in Georgia a much greater utilization of the frost warnings is possible.

VIII.

PROTECTION FROM FROST IN UTAH.

By ALFRED H. THIESSEN, Section Director.

[Dated Weather Bureau, Salt Lake City, Utah, Nov. 27, 1914.]

There are two seasons in Utah when agricultural products are subject to frost. The first is in the spring, from April 1 to May 15, when apricots, cherries, peaches, and sometimes apples need protection. The second is in early fall, when flowers, tomatoes, onions, and alfalfa seed are in danger.

The temperatures as obtained from the ordinary records of cooperative observers give a very accurate idea as to the period when fruit may be menaced by frost in spring, as the thermometers are exposed at about the same elevation as the zone of greatest fruit production. The condition to be most feared is that with a low pressure area over Colorado and a high pressure area over the Northwest. This means the importation of cold air from the north accompanied by a settling of cold air from higher altitudes, and as this condition is usually attended by wind, therefore protection by orchard heaters is very difficult.

The fruit districts center around the following places: Tremonton, Brigham, Ogden, Salt Lake City, and Provo, all on the western slope of the Wasatch Mountains and in the Great Salt Lake drainage area. During the frost period in the spring telegraphic reports are received from the above-named places every day, and an attempt is made from this data and the weather map to forecast the probable minimum temperatures which will occur at those places on the following morning. In a country of such diversified topography as Utah, there is considerable difference in temperature within short distances. The growers, to take advantage of the frost warnings, study their local conditions as compared with the "key stations." The forecasts are given for the key stations, and if a grower has found that his place is consistently warmer or colder than the key station he can then act intelligently when warning for his key station is received.

The method of protection is by heating with the orchard heater, using either coal or oil as fuel. It can not be said that protecting the fruit from frost is universal in Utah. As a matter of fact, only a few farmers, comparatively, are convinced of the practicability of this method or any other method of protecting their fruit. There is a sufficient number, however, who have faith in the oil pot or coal pot, so that the Weather Bureau cooperates with them, as some have very large orchards.

The temperatures obtained by cooperative observers will not indicate very accurately the period at which protection of tomatoes and alfalfa seed in the fall is needed. These crops grow low, and at the special key stations, Willard, Roy, Nephi, Mills, and Deseret, the thermometer shelters are placed on the ground so that the thermometers will indicate the temperature of the surrounding vegetation more nearly than if mounted in their usual position 4 feet above the ground.

The tomato-growing industy is very large and is encouraged by the presence of large canneries in this State. Tons of tomatoes are raised every year, and frequently the last of the crop is spoiled by fall frost, if not protected. Tomatoes, onions, etc., are protected by smudges which are quite effective as very little wind accompanies early fall frosts. The alfalfa seed crop is protected in a much different manner. When alfalfa becomes frosted the seed is blackened, in which condition it sells at a much lower price than the bright, unfrosted seed. It is said, however, that its germinating quality is uninjured. The alfalfa seed grower as soon as he learns that frost of sufficient intensity to blacken the seed is expected, puts to work in the field all the mowers he can, then he stacks the grass. Only a small percentage of the seed is frosted when in this condition, and the crop will then have a high selling value.

It may be asked: Why does not the grower cut his seed earlier? Alfalfa seed matures very unevenly, therefore, an early fall frost catches the seed in all stages of growth, part being in the ripe stage, part fully developed but full of sap, and part not far enough advanced to germinate. During this period, about 10 or 15 days before the crop should be cut, the seed increases in weight from 50 to 100 pounds per acre every 24 hours. The grower, therefore, is tempted to allow the plant to remain standing until the last minute in order to secure this increase, and as seed is now selling for about 12 cents a pound, the increase in weight is valued at from \$6 to \$12 per acre per day.